

The genus *Lepisiota* Santschi, 1926 of the Arabian Peninsula with the description of a new species, *Lepisiota elbazi* sp. nov. from Oman, an updated species identification key, and assessment of zoogeographic affinities

Mostafa R. Sharaf^{1,2}, Abdulrahman S. Aldawood¹,
Amr A. Mohamed³, Francisco Hita Garcia⁴

1 Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia **2** Division of Invertebrate Zoology, American Museum of Natural History, New York, USA **3** Department of Entomology, Faculty of Science, Cairo University, PO Box 12613, Giza, Egypt **4** Biodiversity and Biocomplexity Unit, Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa, Japan

Corresponding author: Mostafa R. Sharaf (antsharaf@gmail.com, mosharaf@ksu.edu.sa)

Academic editor: P. Klimeš | Received 16 January 2020 | Accepted 17 March 2020 | Published 27 April 2020

<http://zoobank.org/4D85CF52-8E50-4D9D-A0E1-38F5E26B6561>

Citation: Sharaf MR, Aldawood AS, Mohamed AA, Hita Garcia F (2020) The genus *Lepisiota* Santschi, 1926 of the Arabian Peninsula with the description of a new species, *Lepisiota elbazi* sp. nov. from Oman, an updated species identification key, and assessment of zoogeographic affinities. Journal of Hymenoptera Research 76: 127–152. <https://doi.org/10.3897/jhr.76.50193>

Abstract

This study updates and summarizes information on the taxonomy and status of the Arabian *Lepisiota* fauna. We describe and illustrate the new species *Lepisiota elbazi* sp. nov. from the Dhofar Governorate, Oman based on the worker caste. The new species is closest to the Arabian species, *L. arabica* Collingwood, 1985 from the southwestern mountains of the Kingdom of Saudi Arabia (KSA) and can be separated by having fewer body hairs (two pairs on the posterior margin of the head, two or three pairs on the promesonotum and, one or two pairs on the first gastral tergite), the longer head, scapes, and propodeal spines, and the shorter mesosoma. We present the first illustrated key to the worker caste of the Arabian species of *Lepisiota* using stacked digital color images to facilitate species determination. The new species is probably endemic to the Dhofar Governorate and seems rare. An up-to-date synoptic checklist of 21 spe-

cies representing the Arabian *Lepisiota* Santschi, 1926 is emended based upon the most recent literature in ant systematics. Five species are excluded from the Arabian *Lepisiota* fauna, *L. arenaria* (Arnold, 1920), *L. erythraea* (Forel, 1910), *L. incisa* (Forel, 1913), *L. sericea* (Forel, 1892a), and *L. simplex* (Forel, 1892) for issues related to previous species misidentification. *Lepisiota carbonaria* (Emery, 1892) is proposed as a senior synonym of *L. depilis* (Emery, 1897) **syn. nov.** The faunal composition of *Lepisiota* species recorded from the Arabian Peninsula can be divided/delineated into two main groups according to their zoogeographical relationships; (1) Afrotropical (11 species-~52.38%); (2) Palearctic (10 species-~47.62%) elements whereas eight species (~38%) are Arabian endemics.

Keywords

Afrotropical Region, Arabian Peninsula, endemism, Formicinae, key, Middle East, new species, Palearctic Region, zoogeography

Introduction

With 135 described species and subspecies, the ant genus *Lepisiota* Santschi, 1926 is one of the most diverse genera of the subfamily Formicinae (Bolton 2020). Most species are broadly spread worldwide in the grasslands, savannahs or woodlands of the Afrotropical, Indomalayan, and Palearctic regions (Brown 2000; Hita Garcia et al. 2013), where they are found nesting directly into the ground, under stones, or in rotten wood while numerous species attend aphids and coccids (Bolton 1973; Hita Garcia et al. 2013). The genus is diagnosed in the worker caste by the following character states (Bolton 1994): antennae 11-segmented; eyes well-developed, ocelli frequently present but sometimes reduced; propodeum armed with a pair of spines, teeth, or tubercles; petiole a scale-like with the dorsal margin bispinose, bidentate or emarginated; acidopore well-developed.

With the lack of revisionary studies for most of the zoogeographical regions of the World, the taxonomic status of the genus is dreadful. Most contributions are restricted to few treatments including to a limited number of papers including faunal lists, descriptions of new species or taxonomic keys for some regions and countries, such as for the Arabian Peninsula (Collingwood and Agosti 1996; Sharaf et al. 2016), Armenia (Arakelian 1994), the Balkans (Agosti and Collingwood 1987), Bulgaria (Atanasov and Dlussky 1992), China (Wu and Wang 1995; Zhou 2001), Egypt (Finzi 1936), Europe and Algeria (André 1882), India, Sri Lanka and Burma (Bingham 1903), Kingdom of Saudi Arabia (KSA) (Collingwood 1985), and Turkestan (Kuznetsov-Ugamsky 1929).

The *Lepisiota* fauna of Oman is poorly known due to a lack of appropriate specialized research, and the few available records are scattered through the literature or have been gleaned from few field surveys only accidentally or incidentally. *Lepisiota arenaria* (Arnold, 1920) and *L. spinisquama* (Kuznetsov-Ugamsky, 1929) were the first species to be recorded from Oman (Collingwood 1985). However, *L. arenaria* is now excluded from the fauna of the Arabian Peninsula due to misidentification. In their treatment of the ant fauna of the Arabian Peninsula, Collingwood and Agosti (1996) reported 20 species from the region, with ten from Oman, including a description of a new species *L. dhofara* Collingwood and Agosti from the Dhofar Governorate. Sharaf et al. (2016)

described *L. omanensis* Sharaf and Monks from Oman and the United Arab Emirates (UAE) and presented a key to the Arabian *Lepisiota* species.

The Arabian Peninsula, including Oman, sits as a semi-isolated block between Eurasia and Africa that overlaps three of the world's key zoogeographical regions; the Afrotropical (Ethiopian), the Oriental and the Palearctic (Larsen 1984; Delany 1989). It is, certainly, the only area where three such regions intersect. Through the Miocene to the Pliocene, it formed a land bridge between the Afrotropical and Oriental regions, allowing the interchange between the two faunas with a far stronger Afrotropical influence. The Afrotropical forms would have been forced out by invading Palearctic species following the severance of the land bridges and the lowering of temperatures during the Pleistocene glaciations, contracted into relict distributions, or evolved to become what are now southern Arabian endemics. The Palearctic species would have been forced northwards or into mountain refugia through the post-glacial increase in aridity and temperature and the remaining Afro-tropical species would have expanded their ranges.

Across through the Bab el Mandeb straits, further invasions from Africa may have been occurred, perhaps swamping such endemics, but invasions from the Oriental region seem have not occurred (Larsen 1980; Delany 1989). Land features affect species distribution and richness (Bestelmeyer and Schooley 1999; Boulton et al. 2005). Geographically, highlighting Oman, Al-Hajar mountains extended in Northeastern part. While, the Dhofar mountain range extend in the South East to Hadhramaut in Yemen. A large stretch of barren desert, acting as a zoogeographical barrier, lies between them. Boundaries among zoogeographical realms in the Arabian Peninsula is continuously a trending controversial topic (Larsen 1984; Rueda et al. 2013; El-Hawagry and Al Dhafer 2015; Ficetola et al. 2017; El-Hawagry et al. 2019).

Essentially, we describe and illustrate a new *Lepisiota* species from the Dhofar Governorate, Oman based on the worker caste. The data reported herein represents the first real insight into this less studied genus and its assemblages in this nearly isolated region. Besides, a short zoogeographical analysis of *Lepisiota* species from the Arabian Peninsula in relation to the classic zoogeographical realms is given. Such an overview of the zoogeographical affinities of this genus in the region may contribute to the somehow confused issue of the boundaries among the main zoogeographical regions in the Arabian Peninsula. Reasons for the observed spatiotemporal variation in community composition are remarked and notes on species habitat preferences are included.

Material and methods

Measurements

The following measurements and indices follow Sharaf et al. (2016).

EL Eye length; maximum diameter of compound eye measured in oblique lateral view.

HL	Head length; maximum distance from the midpoint of anterior clypeal margin to midpoint of posterior margin of head, measured in full-face view.
HW	Head width; maximum width of head behind eyes in full-face view.
ML	Mesonotum length; maximum length of mesonotum in dorsal view.
PH	Petiole height; measured from petiole sternum to apex in profile.
PRW	Pronotal width; maximum pronotal width in dorsal view.
PSL	Propodeal spine length; in dorsocaudal view the tip of the measured spine, its base, and centre of propodeal concavity between spines must all be in focus. Using a dual-axis micrometre the spine length is measured from tip of spine to a virtual point at its base where spine axis meets orthogonally with a line leading to median point of concavity.
SL	Scape length; maximum scape length excluding basal condyle and neck.
TL	Total length; outstretched body length from mandibular apex to gastral apex in profile.
WL	Weber's length; diagonal length of mesosoma in profile from posteroventral margin of propodeal lobe to anterior most point of pronotal slope, excluding neck.

Indices

OI	Ocular index: $EL / HW \times 100$
CI	Cephalic index: $HW / HL \times 100$
SI	Scape index: $SL / HW \times 100$
PSLI	Propodeal spine index: $PSL / HL \times 100$

Species names and zoogeographical boundaries in this work follow the online catalogue of Bolton (2020). In the present work the term southern Arabian Peninsula refers to the Al Sarawat and the Asir Mountains (KSA), the Hajar Mountains stretching along the northern coast of Oman to the United Arab Emirates (UAE), the Dhofar Governorate (Oman), and Yemen.

Institutional abbreviations

BMNH	The Natural History Museum (British Museum, Natural History), London, UK.
KSMA	King Saud University Museum of Arthropods, Plant Protection Department, College of Food and Agriculture Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia.
MSNG	Museo Civico di Storia Naturale “Giacomo Doria”, Genova, Italy.
OUMC	Oxford University Museum, Oxford, UK.

Results

Synoptic species list of the Arabian species of *Lepisiota* Santschi, 1926

Lepisiota arabica (Collingwood, 1985)
Lepisiota bipartita (Smith, 1861)
Lepisiota canescens (Emery, 1897)
Lepisiota carbonaria (Emery, 1892)
 == *Lepisiota depilis* (Emery, 1897) syn. nov.
Lepisiota dammama Collingwood & Agosti, 1996
Lepisiota dhofara Collingwood & Agosti, 1996
Lepisiota dolabellae (Forel, 1911)
Lepisiota elbazi sp. nov.
Lepisiota elegantissima Collingwood & van Harten, 2011
Lepisiota frauenfeldi (Mayr, 1855)
Lepisiota gracilicornis (Forel, 1892)
Lepisiota harteni Collingwood & Agosti, 1996
Lepisiota karawaiewi (Kuznetsov-Ugamsky, 1929)
Lepisiota nigra (Dalla Torre, 1893)
Lepisiota nigrescens (Karavaiev, 1912)
Lepisiota obtusa (Emery, 1901)
Lepisiota omanensis Sharaf & Monks, 2016
Lepisiota opaciventris (Finzi, 1936)
Lepisiota riyadha Collingwood & Agosti, 1996
Lepisiota spinisquama (Kuznetsov-Ugamsky, 1929)
Lepisiota validiuscula (Emery, 1897)

For zoogeographical affinities analysis, all the listed species were assigned to a zoogeographical realm and analyzed altogether. While some relevant notes and suggestions are given, no systematic attempt has been made to place the current zoogeographical patterns in their historical context.

Key to the Arabian species of the genus *Lepisiota* Santschi

The following illustrated key is based on Collingwood and Agosti (1996) and Sharaf et al. (2016):

- | | | |
|---|--|---|
| 1 | Posterior margin of head distinctly compressed in profile (Fig. 1A)..... | 2 |
| – | Posterior margin of head convex in profile (Fig. 1B) | 3 |

- 2 Body pilosity abundant, seven pairs of hairs on posterior margin of head, underside of head and petiole each with two pairs, several pairs on mesosomal dorsum (six on promesonotum, four on mesonotum, and two on propodeal dorsum), femur with hairs (Fig. 1C) (KSA) ***L. arabica***
- Body pilosity less abundant, one or two pairs of hairs on posterior margin of head, underside of head and petiole each without hairs, one to three pairs on promesonotum, and one to two pairs on first gastral tergite; femur bare (Fig. 1D) (Oman) ***L. elbazi* sp. nov.**
- 3 Antennal scape long, surpassing the posterior margin of head by half its length or more **4**
- Antennal scape shorter, surpassing the posterior margin of head by a third of its length or less **17**
- 4 Dorsum of mesosoma and the first and second gastral tergites without standing hairs (Fig. 1E); antennal scape exceptionally long; SI > 200 **5**
- Dorsum of mesosoma with at least one or two pairs of long hairs on pronotum (Fig. 1F); gaster always with some projecting hairs; antennal scape shorter; SI < 200 **6**
- 5 Uniform dark brown or black-brown species; body parts of moderate lengths (SI 200–205; WL 1.00) (KSA) ***L. riyadha***
- Bicolored species, head and gaster dark brown or black-brown, mesosoma, petiole, antennae and legs orange; body exceptionally long and slender (SI > 375; WL 1.91) (Fig. 2A, B) (Oman, UAE) ***L. elegantissima***
- 6 Bicolored, mesosoma paler than gaster, mainly or entirely reddish **7**
- Whole body dark except a small area of the mesonotum more or less red in a few species **9**
- 7 Body sculpture coarse, general appearance opaque (Fig. 2C) (Greece, India, Iran, Israel, Lebanon) ***L. bipartita***
- All parts of the body shining with superficial reticulate sculpture at most (Fig. 2D) **8**
- 8 Uniform light brown, appendages yellow; mesonotum distinctly narrower anteriorly than posteriorly in dorsal view (Fig. 2E); propodeal and petiolar spines acute (Fig. 2F) (KSA) ***L. dammama***
- Head, petiole and gaster dark brown contrasting with the red mesosoma; mesonotum characteristically rectangular in dorsal view (Fig. 3A); propodeal and petiolar spines blunt (Fig. 3B) (Greece, Iran, Israel, KSA, Turkey) ***L. dolabellae***
- 9 Mesosoma densely sculptured; not shining **10**
- Mesosoma superficially sculptured; at least partially shining, in some species completely shining **11**
- 10 Head and mesosoma densely sculptured and completely opaque; propodeal spines long and curved (Fig. 3C) (Oman) ***L. dhofara***
- Head and mesosoma superficially sculptured and slightly shining; propodeal armature short and blunt (Fig. 3D) (Balkan Peninsula, Central Asia, Iran, Kazakhstan, Kuwait, UAE) ***L. karawaiewi***

- 11 Body entirely black, with slight reticulate sculpture at most and shining... **12**
 – Mesosoma usually with small area of mesonotum red; head and mesosoma distinctly sculptured and not shining **16**
- 12 Propodeal and petiolar spines reduced (Fig. 3E), petiole dorsum narrow and rounded, with reduced armature; antennal scapes shorter, SI 150–155 (Croatia, Egypt, Greece, Iberian Peninsula, Italy, Kyrgyzstan, Macedonia, Montenegro, Oman, UAE) ***L. nigra***
 – Propodeal and petiolar armature both well-developed with long curved spines (Fig. 3F); antennal scape long, SI 165–200 **13**
- 13 Propodeum and first gastral tergite with some fine surface sculpture; first gastral tergite with characteristic violet reflection; SI 195–200 (Egypt, Israel, KSA, UAE) ***L. opaciventris***
 – Whole body smooth; first gastral tergite without reflection of any type; SI 165–195 **14**
- 14 Propodeal short, less than 0.10 mm, moderately curved; antennal scape long, SI 175–195 (Yemen, Eritrea, Israel, UAE) ***L. gracilicornis***
 – Propodeal spines long, more than 0.12 mm, and distinctly curved; antennal scape shorter, SI 165–170 **15**
- 15 Body dark brown; propodeal spines slightly curved, in profile appearing at level of the petiolar spines; body slightly shining; scape shorter (SI 170), cephalic index smaller (CI 79), petiolar height lower in profile (0.41); appressed pubescence abundant on body (Iran, Kazakhstan, KSA, Oman, Socotra) ***L. spinisquama***
 – Body black, propodeal spines strongly curved (Fig. 4A), in profile appearing much higher than level of petiolar spines; body more strongly shining; scape longer (SI 230–233), cephalic index greater (CI 86–88), petiolar height larger in profile (0.25–0.37); pubescence on body scattered (Oman, UAE) ***L. omanensis***
- 16 Paler species, mesosoma, legs and antennae orange, distinctly contrasting the brown head and gaster; pronotum with one pair of hairs (Fig. 4B) (widespread in Palearctic region) ***L. frauenfeldi***
 – Uniform black or black-brown; pronotum without hairs (Fig. 4C) (Tunisia, UAE) ***L. nigrescens***
- 17 Head and mesosoma densely punctate and dull **18**
 – Head and mesosoma smooth or superficially sculptured rugulose, and shining **20**
- 18 Bicolored species, with mesosoma reddish, head, petiole, and gaster brown (Yemen) ***L. harteni***
 – Uniform brown or black-brown species **19**
- 19 Propodeal spines reduced or indistinct (Fig. 4D); whole gastral dorsum covered with abundant pale hairs (Fig. 5A) (Ethiopia, Eritrea, Israel, KSA) ***L. obtusa***
 – Propodeal spines well-developed in the form of two broadly-based blunt tubercles in profile (Fig. 5B); gastral pilosity restricted to few pairs on the poste-

- rior margin of tergites (Fig. 5B) (Djibouti, KSA, Oman, Somalia, Yemen)
 *L. carbonaria* (= *L. depilis* syn. nov.)
- 20 Posterior margin of head in full-face view fringed with about seven pairs of
 stiff hairs (Fig. 5C); body pilosity brown (Namibia, Somalia, Yemen, Zimba-
 bwe)..... *L. validiuscula*
- Posterior margin of head in full-face view with only two to three of stiff hairs
 (Fig. 5D); body pilosity yellow (Guinea, Israel, Kenya, KSA, Somalia, Oman,
 Yemen) *L. canescens*

***Lepisiota elbazi* Sharaf & Hita Garcia, sp. nov.**

<http://zoobank.org/218E57C6-A0CA-4C9D-B4E3-EC9EBF831AEC>

Figs 1A, D, 6A–C

Type material. Holotype: pinned worker from OMAN: DHOFAR: Ayn Razat, 17.12443N, 54.23832E, 98 m, 20.xi.2017, [CASENT0872069](#), SF, (M. R. Sharaf).

Paratype: one pinned worker with same data as holotype, [CASENT0922860](#), (King Saud University Museum of Arthropods (KSMA), Plant Protection Department, College of Food and Agriculture Sciences, King Saud University, Riyadh, KSA).

Holotype worker. Measurements (paratype in parentheses): EL 0.17 (0.20); HL 0.82 (0.87); HW 0.57 (0.62); ML 0.50 (0.57); PH 0.30 (0.32); PRW 0.45 (0.50); PSL 0.12 (0.15); SL 1.07 (1.15); TL 3.20 (3.50); WL 1.40 (1.50). Indices: CI 70 (71); OI 30 (32); PSLI 15 (17); SI 188 (185).

Diagnosis. This new species can be distinguished from its regional congeners by the following combination of characters: in profile, posterior margin of head anteroposteriorly compressed; limited number of hair pairs on body: two pairs on posterior margin of head, two to three pairs on promesonotum, and one to two pairs on first gastral tergite.

Description. Worker. Head. Elongate, distinctly more than $1.3\text{--}1.6 \times$ longer than broad, with straight posterior margin and feebly convex lateral margins; posterior margin of head, in profile, anteroposteriorly compressed; antennal scapes when laid back from their insertions surpassing posterior margin of head by more than one third of length (SI 185–188); eyes of moderate size (OI 30–32), with the anteriormost point of the eye lies touching the midlength of head in full-face view; anterior clypeal margin strongly convex anteriorly and dorsally, and with raised lateral margins; frontal triangle opened posteriorly; masticatory margin of mandibles armed with four teeth, the first tooth being longest, the third being smallest, the second and fourth teeth are of moderate size and subequal (counting from apex). **Mesosoma.** Promesonotum convex in profile; first half of mesonotal outline descending posteriorly into a concave curve then elevated and descending posteriorly in a straight line to an impressed metanotal groove; propodeal spines long and acute in profile (PSLI 15–17), propodeal spines in profile rising slightly to the rear from the level of the propodeal dorsum. **Petiole.** Acutely dorsally bispinose. **Pilosity.** First two-thirds of scape without hairs, distal quarter with a few stiff hairs, funiculus with dense appressed pubescence; cephalic dorsum

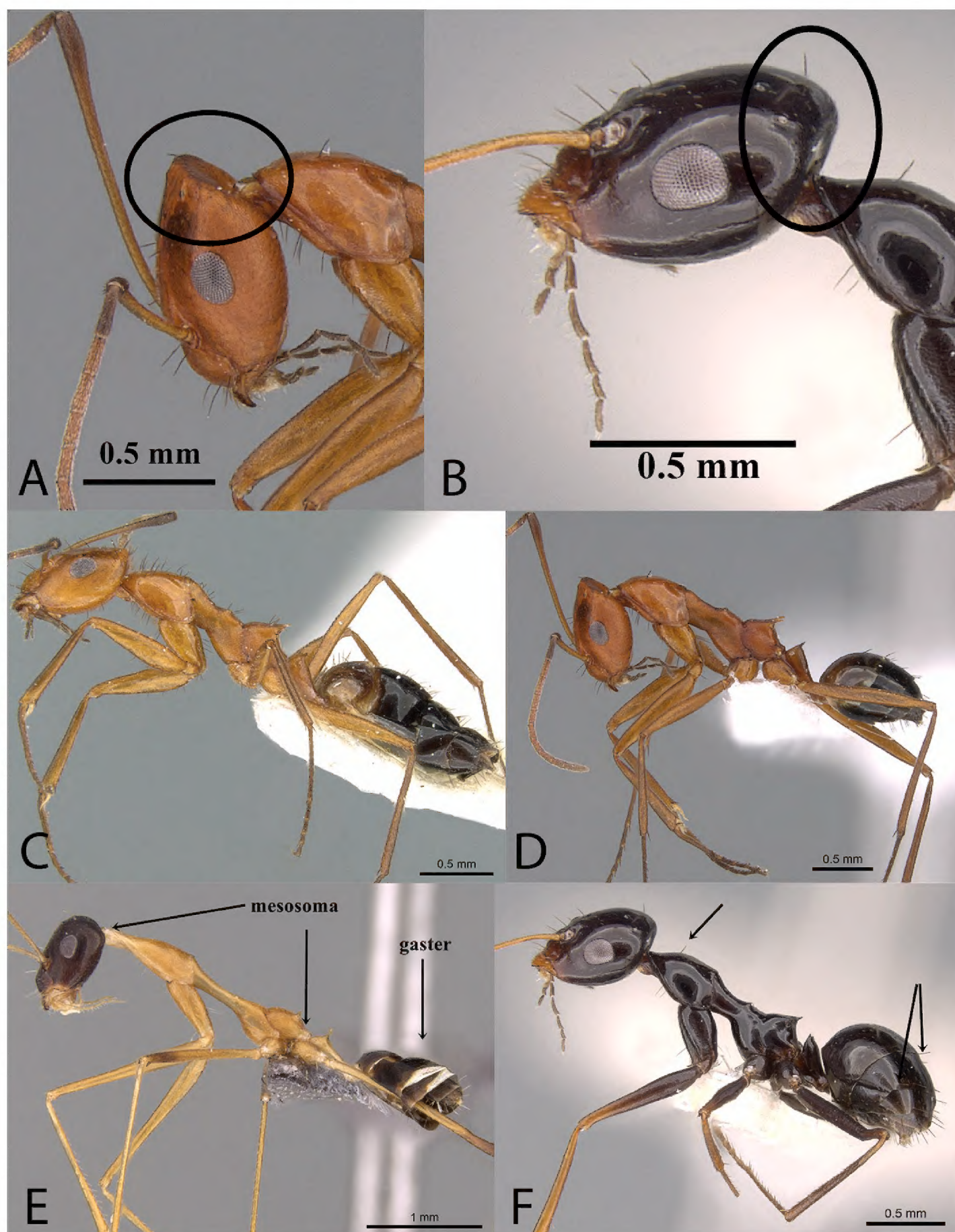


Figure 1. **A** head of *L. elbazi* sp. nov. in profile, [CASENT0922860](#) (Michele Esposito) **B** head of *L. gracilicornis* in profile, [CASENT0906458](#) (Cerise Chen) **C** body of *L. arabica* in profile, [CASENT0906264](#) (Estella Ortega) **D** body of *L. elbazi* sp. nov. in profile, [CASENT0922860](#) (Michele Esposito) **E** body of *L. elegantissima* in profile, [CASENT0922860](#) (Michele Esposito) **F** body of *L. gracilicornis* in profile, [CASENT0906458](#) (Cerise Chen), www.AntWeb.org.

with several pairs of stiff, black, long, blunt hairs (hair length 0.10–0.12) arranged as follow: two on anterior clypeal margin, one on posterior clypeal margin, one at end of frontal carinae; one close to level of anterior margins of eyes; one behind level of

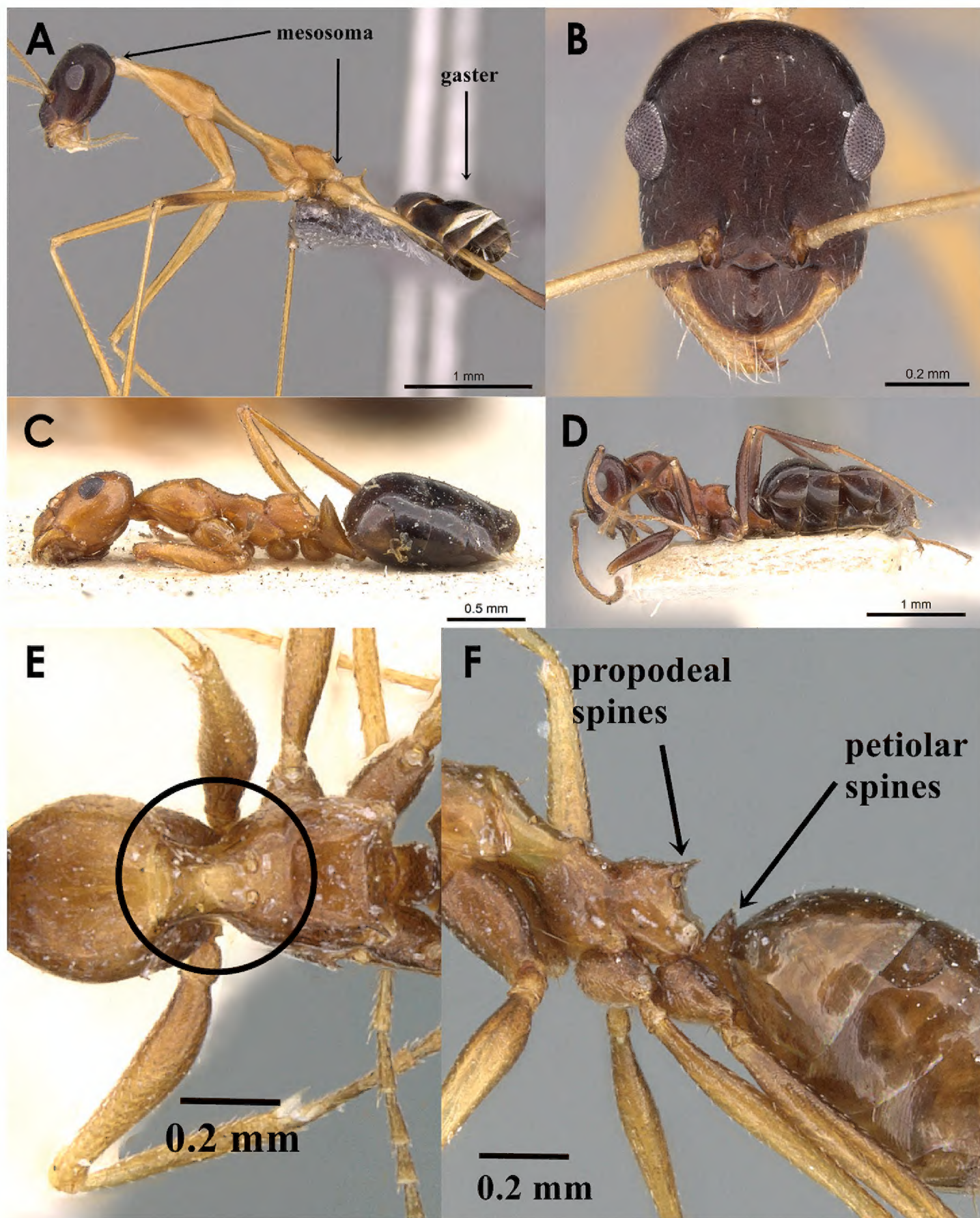


Figure 2A–F. **A** body of *L. elegantissima* in profile, [CASENT0922860](#) (Michele Esposito) **B** head of *L. elegantissima* in full-face view, [CASENT0922860](#) (Michele Esposito) **C** body of *L. bipartita* in profile, [CASENT0903167](#) (Zach Lieberman) **D** body of *L. dolabellae* in profile, [CASENT0249883](#) (Shannon Hartman) **E** mesosoma of *L. dammama* in dorsal view showing mesonotum, [CASENT0906337](#) (Estella Ortega) **F** body of *L. dammama* in profile showing propodeal and petiolar spines, [CASENT0906337](#) (Estella Ortega), www.AntWeb.org.

mid-length of eyes; two at posterior margin of head; promesonotum with one to three pairs of hairs; mandibular surfaces with fine long pale hairs; gaster with several scattered hairs. **Sculpture.** Cephalic, clypeal surfaces, and promesonotal dorsum faintly

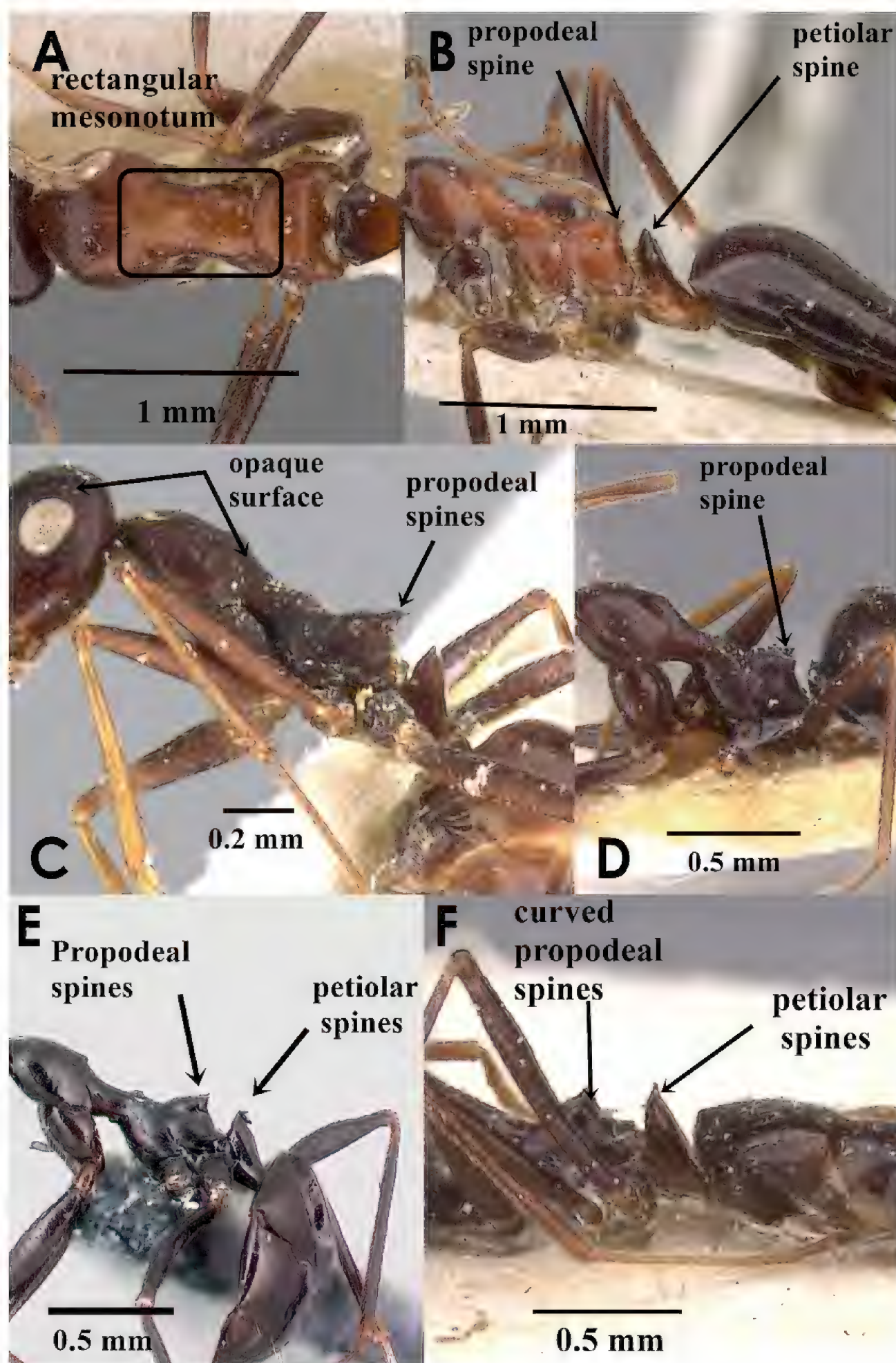


Figure 3A–F. **A** mesosoma of *L. dolabellae* in dorsal view showing mesonotum, [CASENT0909887](#) (Zach Lieberman) **B** body of *L. dolabellae* in profile propodeal and petiolar spines, [CASENT0909887](#) (Zach Lieberman) **C** body of *L. dhofara* in profile showing surface sculpture and propodeal spines, [CASENT0906340](#) (Estella Ortega) **D** mesosoma of *L. karawaiewi* in profile showing propodeal spines, [CASENT0912405](#) (Will Ericson) **E** body of *L. nigra* in profile showing propodeal and petiolar spines, [CASENT0179896](#) (Erin Prado) **F** Body of *L. spinisquama* in profile showing petiolar spines, [CASENT0922270](#) (Michele Esposito), www.AntWeb.org.

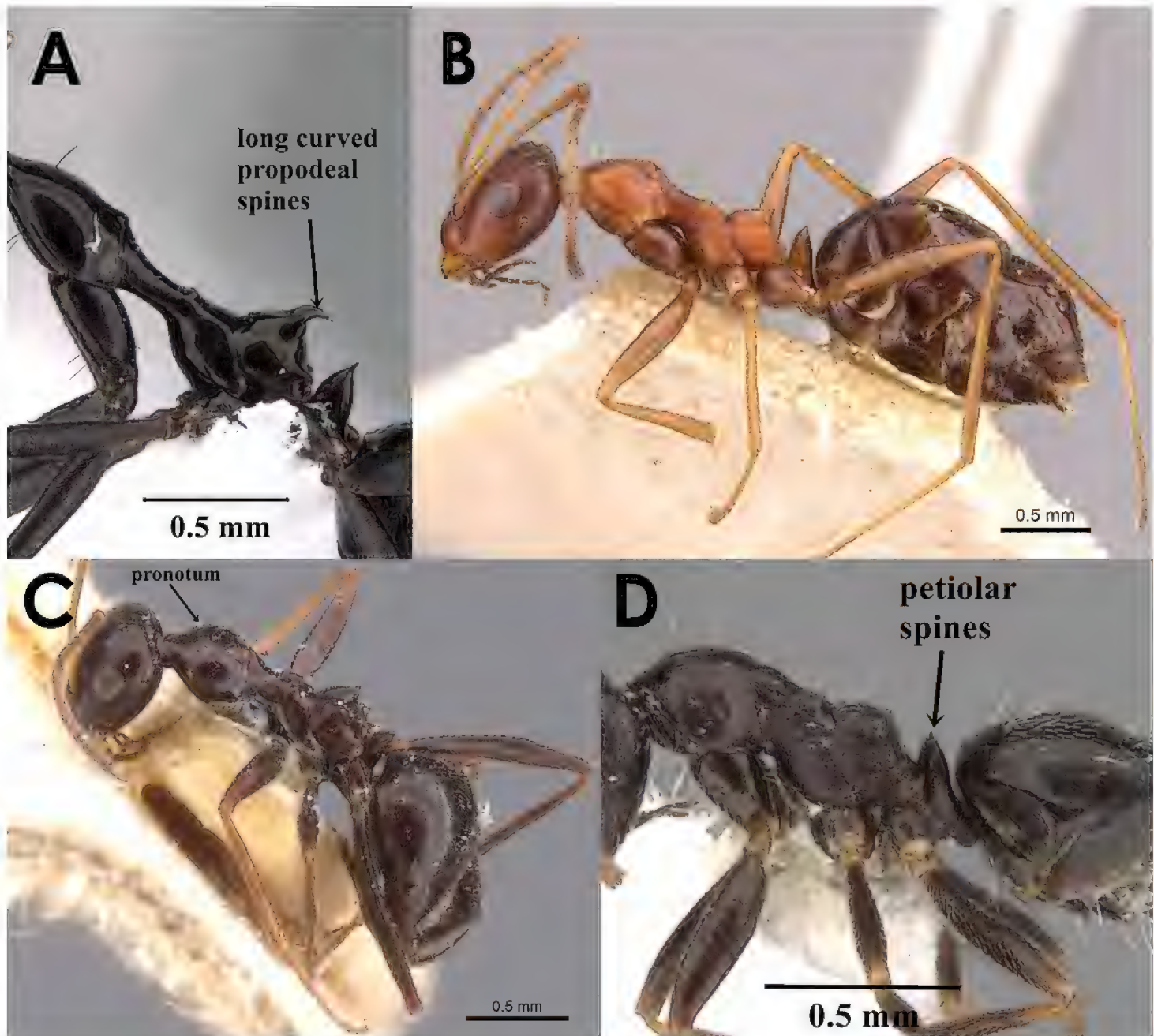


Figure 4A–D. **A** mesosoma of *L. omanensis* in profile showing propodeal spines, [CASENT0922278](#) (Michele Esposito) **B** body of *L. frauenfeldi* in profile propodeal and petiolar spines, [CASENT0909884](#) (Zach Lieberman) **C** body of *L. nigrescens* in profile, [CASENT0912400](#) (Will Ericson) **D** body of *L. obtusa* in profile showing reduced petiolar spines, [CASENT0280477](#) (Shannon Hartman), www.AntWeb.org.

but finely reticulate-rugulose, moderately shiny, mandibular surface smooth and shining; mesonotum, propodeum, and petiole distinctly reticulate-punctate; first gastral tergite smooth and shining. **Color.** Bicolored species, head, mesosoma, petiole yellow or red-yellow, distal end of scapes, first funicular segment and mandibular teeth darker; gaster mostly dark brown to black with first tergite of slightly lighter brown.

Etymology. The patronymic name honors Prof. Farouk El-Baz, the Egyptian space scientist, Boston University, USA in recognition of his distinguished scientific achievements.

Remarks. The occurrence of hairs and their distribution on the surface of the body are diagnostic characters for the recognition of species in many ant genera, notably used in the taxonomy of the genus *Lepisiota* (Collingwood 1985; Collingwood and Agosti 1996). *Lepisiota elbazi* is not similar to any of the known Arabian *Lepisiota*, except the Arabian endemic species *L. arabica* (Collingwood, 1985) described from the

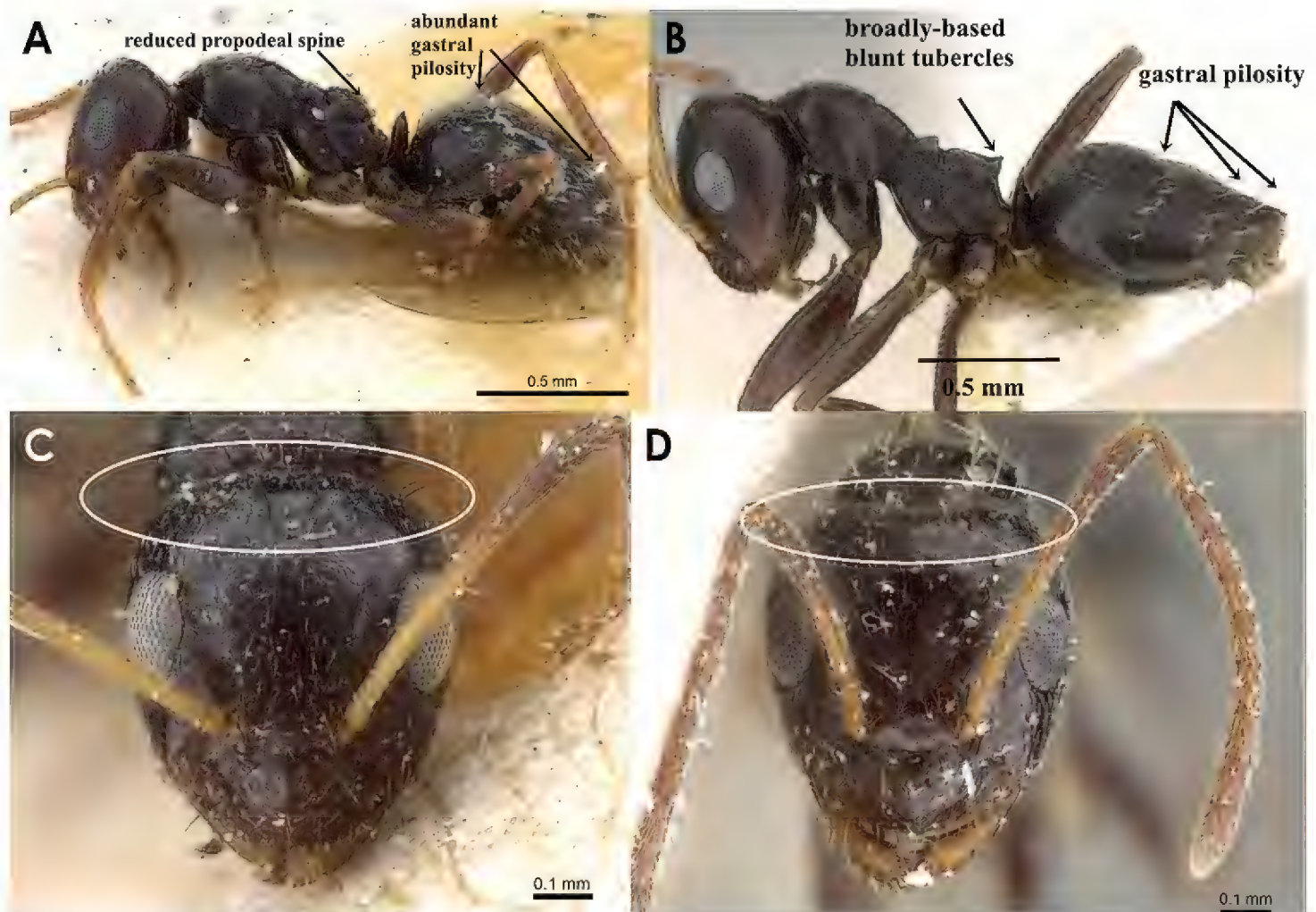


Figure 5A–D. **A** body of *L. obtusa* in profile showing propodeum and gastral pilosity, [CASENT0905150](#) (Zach Lieberman) **B** body of *L. carbonaria* in profile showing propodeal spines and gastral pilosity, [CASENT0906261](#) (Estella Ortega) **C** head of *L. validiuscula* in full-face view showing pilosity on posterior margin, [CASENT0280473](#) (Shannon Hartman) **D** head of *L. canescens* in full-face view showing pilosity on posterior margin, [CASENT0905153](#) (Zach Lieberman), www.AntWeb.org.

southwestern Asir Mountains, KSA. Both species are bicolored and have a compressed posterior margin of the head when seen in profile, acute and long propodeal spines, stiff and blunt hairs, impressed metanotal groove, characteristically paler first gastral tergite and similar body sculpture. The compressed profile of the posterior margin of the head sets the two species apart from any of the Arabian *Lepisiota*, as those all have a rounded profile to the posterior margin of the head.

The two species can be separated by the number of body hairs and dimensions. *Lepisiota elbazi* has fewer hairs on the posterior margin of the head (two pairs), on the mesosoma (two to three pairs on promesonotum), and on the first gastral tergite (one to two pairs). *Lepisiota arabica* has more than seven pairs of hairs on the posterior margin of the head, many pairs scattered on the mesosomal dorsum (six pairs on promesonotum, four pairs on mesonotum, and two pairs on the propodeal dorsum), and several pairs on the first gastral tergite. Additionally, *L. elbazi* has a greater head length (HL 0.82–0.87 vs. HL 0.72–0.77 in *L. arabica*), longer scapes (SL 1.07–1.15, SI 185–188 vs. SL 0.87–0.89, SI 155–159), and relatively longer head (HL 0.82–0.87 vs. HL 0.73–0.75).

Ecological and biological notes. Both workers of the new species were collected at Ayn Razat (Fig. 7) and were foraging in leaf litter covering dry soil under an *Acacia* tree.

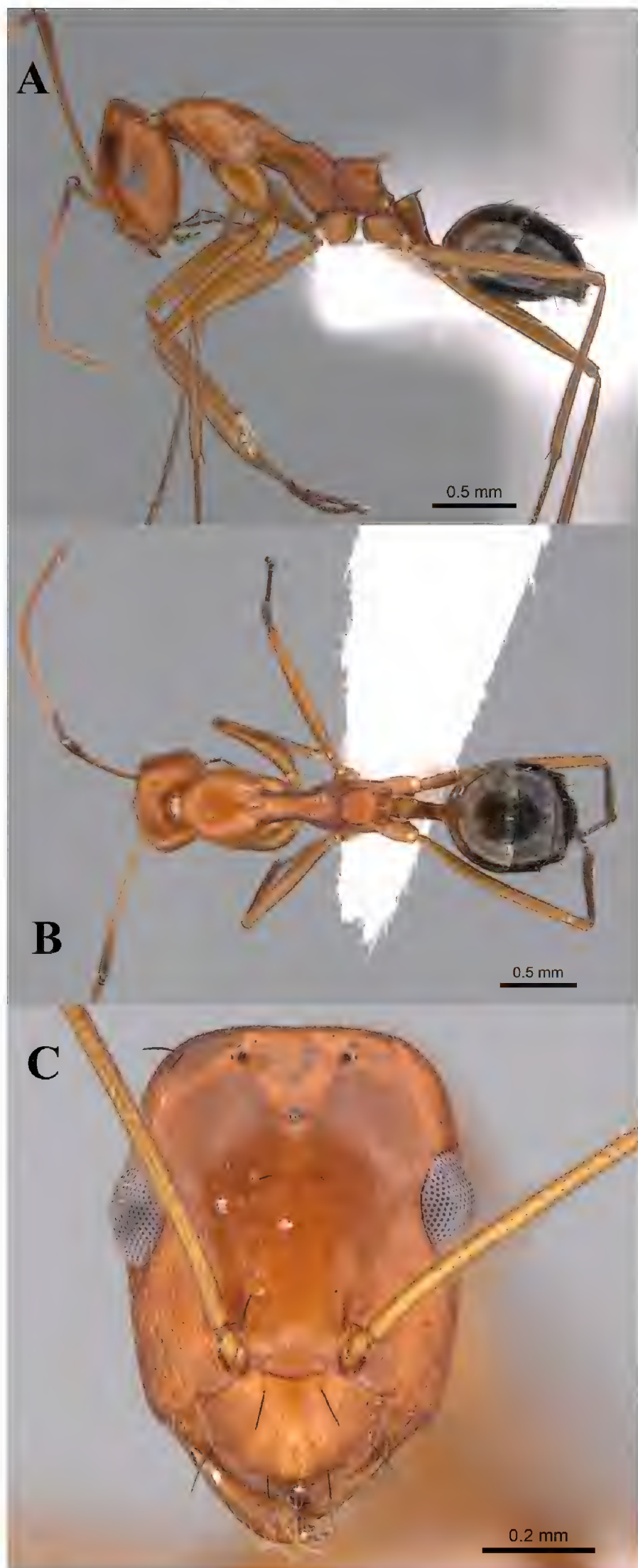


Figure 6A–C. *Lepisiota elbazi* sp. nov. **A** body in profile **B** body in dorsal view **C** head in full-face view, CASENT0922860, (Michele Esposito), www.AntWeb.org.



Figure 7. Ayn Razat, the type locality of *Lepisiota elbazi* sp. nov. (Mostafa Sharaf).

Geographic range. Oman.

Queen and male. Not known.

Newly proposed synonymy

Lepisiota carbonaria (Emery, 1892)

Acantholepis carbonaria Emery, 1892 [Combination in *Lepisiota* by Bolton, 1995]

Acantholepis capensis subsp. *depilis* Emery, 1897 [Raised to species by Collingwood, 1985; Combination in *Lepisiota* by Bolton, 1995] syn. nov.

Material examined of *L. carbonaria*. SOMALIA: 1 syntype worker, Obbia, [CASENT0905149](#), (MSNG); 1 w, Sheikh, 1939, (the Governor), (Pres. By Imp. Inst. Ent.), (B. M. 1946-273), (BMNH, E, 1018291), [CASENT0906261](#); ETHIOPIA: 1 w, Turmi, 04°58'N, 36°29'E, 21.i.2010, (Serge Guiraud), (Hand collecting) (B. Taylor det.) (OUMC); OMAN: 5 w, Dhofar, Ayn Razat, 17.12443N, 54.23832E, 98 m, 20.xi.2017, (M. R. Sharaf), (MRS0399), [CASENT0922845](#) (KSMA).

Material examined of *L. depilis*. SOMALIA: 1 syntype worker, Bricchetti, [CASENT0905154](#), (MSNG).

Remarks. *Lepisiota carbonaria* was originally described by Emery (1892) from Somalia and in 1897 he described *L. depilis* as a subspecies of *Acantholepis capensis* from the same country. Collingwood (1985) was the first to draw the attention of the difference between *L. depilis* and *L. capensis* based on the reduced mesosomal pilosity and the dense mesosomal sculpture of the former which make it sufficiently distinguishable from the later species that has abundant mesosomal pilosity and shining body appearance. However, in his original description of *depilis*, Emery pointed out the remarkable similarities between *depilis* and *carbonaria* which are mainly the dense sculpture on head and mesosoma and dull appearance of these two body parts, and the gastral pilosity which in the form of a row of setae on the posterior margins of the gastral tergites. Emery was correct and our examination of the type material of the two taxa confirms his notes and reveals a straightforward synonymy. The two species have the same body color, dense sculpture, reduced blunt propodeal spines, dull head and mesosoma, and shining gastral tergites with few hairs on margins of tergites. We consider *L. carbonaria* a senior synonym of *L. depilis*.

Species excluded from the Arabian fauna

The following species are excluded from the Arabian *Lepisiota* fauna and are considered as misidentification.

Lepisiota arenaria (Arnold, 1920)

Collingwood and Agosti (1996) wrote “this elegant species with red head and mesosoma” but the type material ([CASENT0903150](#)) is no more than uniform dull yellow.

Lepisiota erythraea (Forel, 1910)

Collingwood (1985) stated that this species has a rounded petiole with very shallow emargination, and mesosoma entirely without dorsal hairs. The type material ([CASENT0909880](#)) has one pair of long, sharp, triangular petiolar spines and mesosoma with some pairs of hairs.

Lepisiota incisa (Forel, 1913)

This is an eastern African species that seems unlikely to be found in Arabia. Collingwood (1985)’s key mentioned that the mesosomal pilosity is restricted to the pronotum or nil but examination of the type material ([CASENT0909876](#)) reveals abundant mesosomal and body pilosity.

Lepisiota sericea (Forel, 1892a)

In their key, Collingwood and Agosti (1996) stated that “this species appeared bicolor-
ed with reddish mesosoma lighter than gaster, or entirely reddish. The type material
([CASENT0909885](#)) is uniformly dark brown”.

Lepisiota simplex (Forel, 1892)

Collingwood and Agosti (1996) had “mesosoma with pale, thin hairs, that are re-
stricted to pronotum”. The type material ([CASENT0909878](#)) has several pairs of hairs
scattered on the mesosoma including the propodeum.

Zoogeography of the Arabian *Lepisiota*:

Table 1. Zoogeographic affinities of the Arabian *Lepisiota* (Bolton 2020).

Species	Type locality	Zoogeography	Afrotropical species recorded from southern Arabian Peninsula	References
<i>Lepisiota arabica</i>	Saudi Arabia	(Endemic) Afrotropical affinity	+	Collingwood 1985
<i>Lepisiota bipartita</i>	Lebanon	Palearctic		Collingwood and Agosti 1996
<i>Lepisiota canescens</i>	Somalia	Afrotropical	+	Collingwood 1985; Collingwood and Agosti 1996
<i>Lepisiota carbonaria</i>	Somalia	Afrotropical	+	Collingwood 1985; Collingwood and Agosti 1996
<i>Lepisiota dammama</i>	Saudi Arabia	(Endemic) Palearctic affinity		Collingwood and Agosti 1996
<i>Lepisiota dhofara</i>	Oman	(Endemic) Afrotropical affinity	+	Collingwood and Agosti 1996
<i>Lepisiota dolabellae</i>	Turkey	Palearctic		Collingwood 1985; Colling- wood and Agosti 1996
<i>Lepisiota elbazi</i> sp. nov.	Oman	(Endemic) Afrotropical affinity	+	
<i>Lepisiota elegantissima</i>	United Arab Emirates	(Endemic) Afrotropical affinity	+	Collingwood et al. 2011
<i>Lepisiota frauenfeldi</i>	Yugoslavia	Palearctic		Collingwood 1985; Colling- wood and Agosti 1996
<i>Lepisiota gracilicornis</i>	Yemen	Afrotropical	+	Collingwood 1985; Collingwood and Agosti 1996
<i>Lepisiota harteni</i>	Yemen	(Endemic) Afrotropical affinity	+	Collingwood and Agosti 1996
<i>Lepisiota karawaiewi</i>	Kazakhstan	Palearctic		Collingwood and Agosti 1996
<i>Lepisiota nigra</i>	Italy	Palearctic		Collingwood and Agosti 1996
<i>Lepisiota nigrescens</i>	Tunisia	Palearctic		Collingwood 1985; Colling- wood and Agosti 1996
<i>Lepisiota obtusa</i>	Ethiopia	Afrotropical	+	Collingwood 1985; Collingwood and Agosti 1996
<i>Lepisiota omanensis</i>	Oman	(Endemic) Afrotropical affinity	+	Sharaf et al. 2016
<i>Lepisiota opaciventris</i>	Egypt	Palearctic		Collingwood 1985; Colling- wood and Agosti 1996
<i>Lepisiota riyadha</i>	Saudi Arabia	(Endemic) Palearctic affinity		Collingwood and Agosti 1996
<i>Lepisiota spinisquama</i>	Kazakhstan	Palearctic		Collingwood 1985; Colling- wood and Agosti 1996
<i>Lepisiota validiuscula</i>	Somalia	Afrotropical	+	Collingwood and Agosti 1996

Discussion

The biogeography of the Arabian Peninsula has always been a subject of interest and sometimes controversial by researchers, and this is undoubtedly due to its geographic location at the interchange of three major zoogeographical realms, the Afrotropical, the Palearctic, and the Oriental regions. This pivotal geographical location has made the Arabian Peninsula harbor elements of all zoogeographic regions with a notable influence of the Afrotropical species documented for the southwestern mountains of the Arabian Peninsula, Yemen, the Dhofar Governorate, and Jabal Al Akhdar in Oman (e.g. Guichard 1980; Larsen and Larsen 1980; Larsen 1984; Collingwood 1985; Cowie 1989; Collingwood and Agosti 1996; Pesenko and Pauly 2009; Sharaf and Aldawood 2011, 2012, 2019; Sharaf et al. 2012a, b, c; El-Hawagry et al. 2013, 2016a, b, 2017; Abdel-Dayem et al. 2019).

Our new collections and previous literature records (Collingwood 1985; Collingwood and Agosti 1996; Collingwood et al. 2011) indicate that the *Lepisiota* fauna of the Arabian Peninsula includes 21 species, which is clearly represented by taxa of the Afrotropical and the Palearctic regions (Table 1, Fig. 8). About 53% of these species have strong affinities with the Afrotropical Region (11 species), followed by the Palearctic elements (including western and eastern boundaries of the Palearctic region) with about 48% (10 species). This Afrotropical preponderance has been previously recognized by numerous studies (e.g. Guichard 1980; Larsen and Larsen 1980; Larsen 1984; Collingwood 1985; Cowie 1989; Waterston and Pittaway 1991; Schneider and Krupp 1993; Collingwood and Agosti 1996; Taiti et al. 2000; Hausmann 2009; Pesenko and Pauly 2009; Sharaf and Aldawood 2011, 2012, 2019; Neubert and van Damme 2012; Sharaf et al. 2012a, b, c; El-Hawagry et al. 2013, 2016a, b, 2017; Hájek and Reiter 2014; Ball et al. 2015; Abdel-Dayem et al. 2019). The close Afrotropical affinity of the taxa mentioned in the above studies supports the direct linkage of Afrotropical lineages with the Arabian Peninsula. However, the Oriental influence is absent but it is anticipated some taxa from the region might exist with extensive collecting. The minor Oriental influence is documented by some studies as Larsen (1984) on the Arabian fauna of the butterflies (Larsen 1984), Penati and Vienna (2006) on the Arabian Histeridae, and Abdel-Dayem et al. (2019) on the Carabidae of Shada Al-A'Ala Nature Reserve, Southwestern KSA. Obviously much more collecting efforts must be done to allow an in-depth zoogeographical treatment for confirming speculation.

These distributional patterns indicate that zoogeographically the area of the Arabian Peninsula is not a homogeneous unit. Our analysis of *Lepisiota* zoogeographic affinities generally supports Larsen and Larsen (1980), Larsen (1984), Abdel-Dayem et al. (2019), Cowie (1989), Penati and Vienna (2006), Rueda et al. (2013), Sharaf et al. (2014), Ficetola et al. (2017), Delany (1989), El-Hawagry et al. (2019) arguments that a major zoogeographic discontinuity exists within the region. Despite this, as mentioned above about 38% (8 out of 21 spp.) of the species appear to be endemic to the region.

The geographic location of the Arabian Peninsula at the conjunction of three zoogeographical regions make the delineation of the borders among these three bioregions is a difficult task and this subject is often pay the attention of biogeographers.

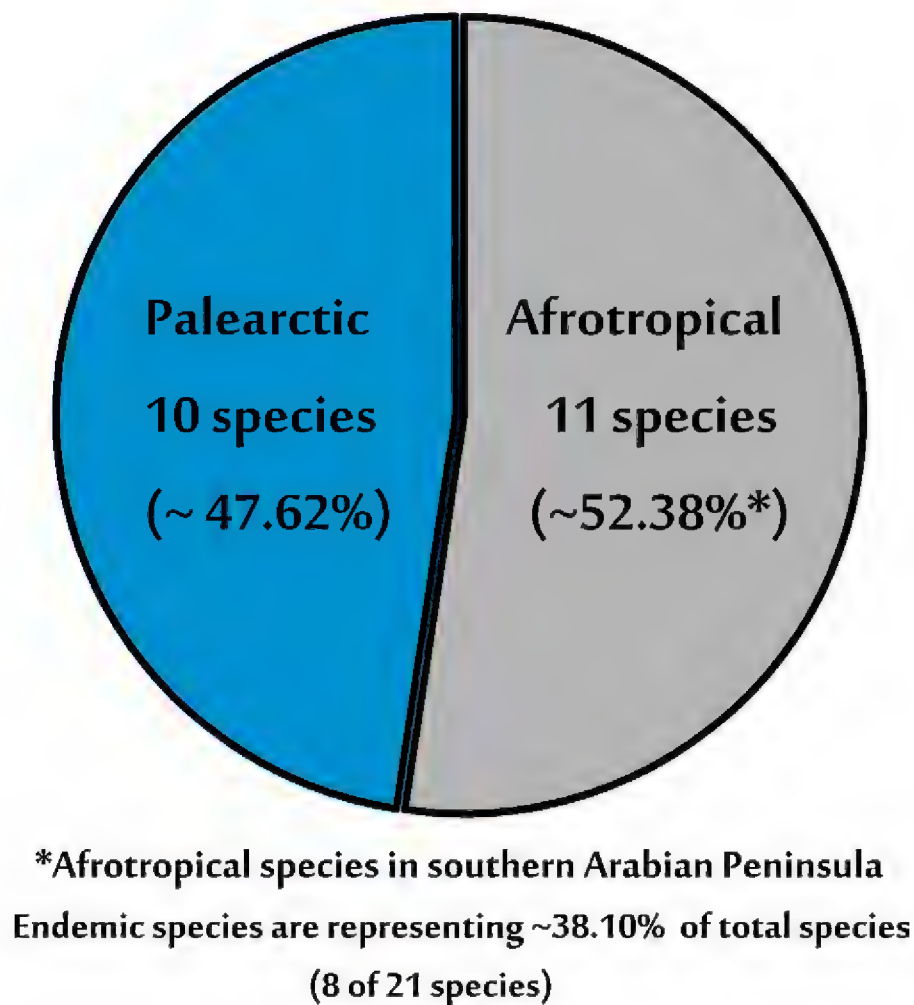


Figure 8. Zoogeographic analysis of the Arabian *Lepisiota*.

Numerous studies have considered that the southwestern Arabian Peninsula, which includes the Al Sarawat Mountain and the Asir Mountains (KSA) and Yemen, with clear Afrotropical affinities (e.g. Larsen and Larsen 1980; Collingwood 1985; Collingwood and Agosti 1996; Taiti et al. 2000; Hausmann 2009; Pesenko and Pauly 2009; Sharaf and Aldawood 2011, 2012, 2019; Sharaf et al. 2012a, b, c; El-Hawagry et al. 2013, 2016a, b, 2017; Hájek and Reiter 2014; Ball et al. 2015; Abdel-Dayem et al. 2019). Some studies conjoin the Dhofar Governorate, Jebel Akhdar (Oman) and the Hajar Mountains that extend between Oman and the UAE to the Arabian areas of Afrotropical elements but with relatively lesser degrees of Afrotropical affinities (Larsen 1984; Cowie 1989; Delany 1989; Penati and Vienna 2006).

Our available data of the distribution of the Arabian fauna of *Lepisiota* clearly show a confined distribution of all the Afrotropical species and the endemic species to the southern Arabian Peninsula, whereas those Afrotropical species are not represented in the arid regions of the Arabian deserts and obviously are replaced by taxa of the Palearctic region. These data fully coincide with the findings of several studies that draw the boundaries between the Afrotropical and the Palearctic regions of the Arabian Peninsula as a line connecting the mountainous coastal strip that is parallel to the Red Sea in the western Arabian Peninsula starting from Taif and southwards to Yemen, parts of Oman (Dhofar, Jebel Akhdar) and the UAE) (the Hajar Mountains) (Fig. 9) (Larsen 1984; Cowie 1989; Delany 1989; Penati and Vienna 2006).

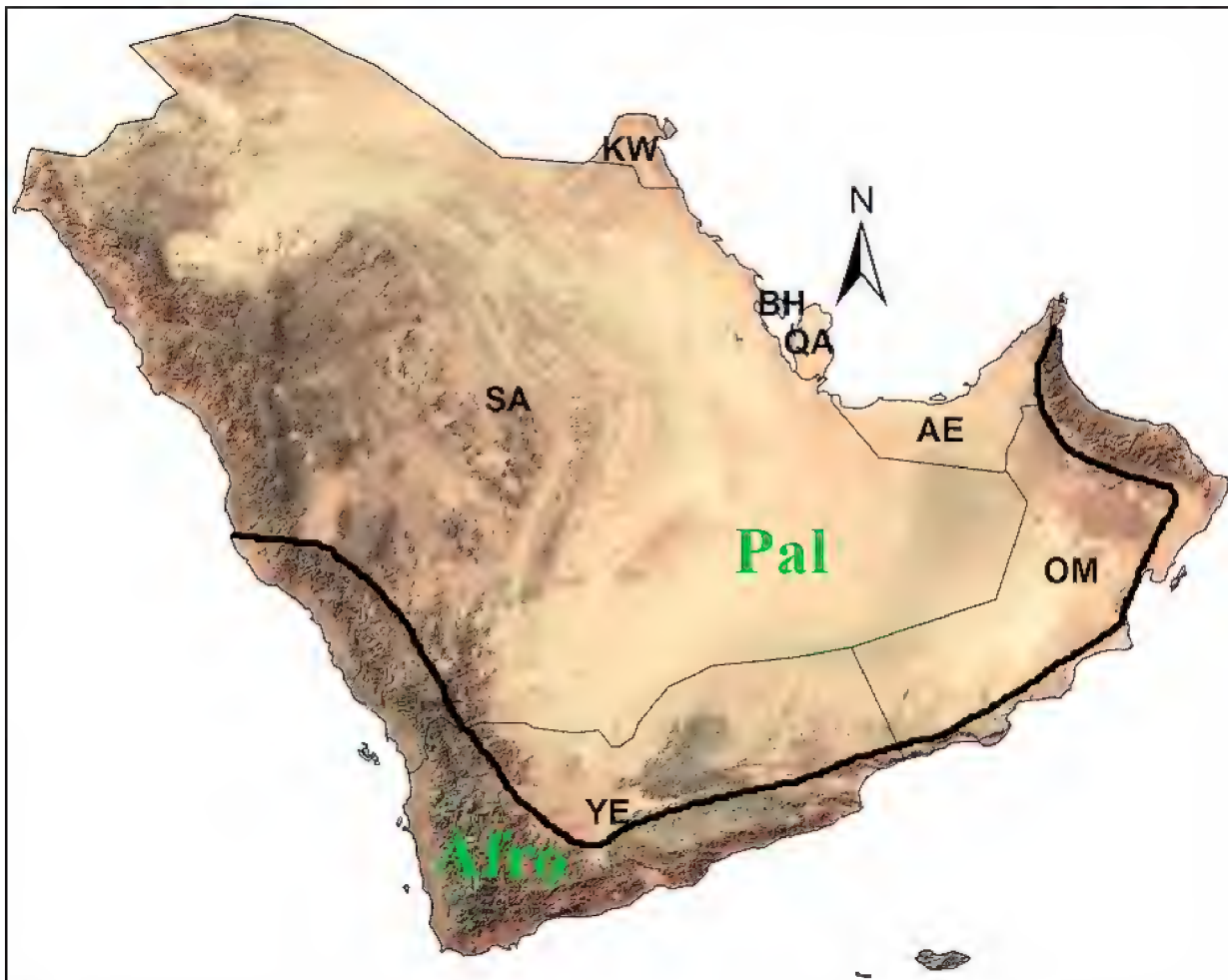


Figure 9. Zoogeographic boundaries between the Afrotropical and the Palearctic regions of the Arabian Peninsula, AE: United Arab Emirates, BH: Bahrain, KW: Kuwait, OM: Oman, QA: Qatar, SA: Saudi Arabia, YE: Yemen.

The distribution pattern of the Arabian *Lepisiota* is restricted to two major regions of the Arabian Peninsula: the forests of the southwestern mountains and the vast surrounding deserts. The distribution of the Afrotropical species is obviously confined to forests of the southern Arabian Peninsula of the KSA, Yemen, and Oman, whereas the Palearctic species are mainly represented outside this geographic range and precisely correlated to the desert ecosystems of the Arabian Peninsula. Hence, while the Afrotropical influence decreases towards the north and east, the Palearctic influence increases correspondingly. This geographic correlation is likely related to habitat availability, soil nature, and vegetation cover in the two ecosystems. Environmental impact obviously favors the spread and maintenance of a species over another and can result in a vast distribution (Larsen 1984; Cowie 1989).

The Arabian *Lepisiota* fauna, however, includes a noteworthy proportion of apparently endemic species (38.10%) represented by eight species, *L. arabica*, *L. dammama*, *L. dhofara*, *L. elbazi* sp. nov., *L. elegantissima*, *L. harteni*, *L. omanensis*, and *L. riyadha*. This high degree of endemism for the Arabian Peninsula is documented for several groups of animals including amphibians (Arnold 1980), reptiles (Šmíd 2010; Melnikov and Pierson 2012), birds (Ball et al. 2015), arthropods of different groups including Isopoda (Taiti et al. 2000), Lepidoptera (Larsen and Larsen 1980; Hausmann 2009), Isoptera (Cowie 1989), Odonata (Waterston and Pittaway 1991; Schneider and Krupp 1993), Coleop-

tera (Hájek and Reiter 2014), and Hymenoptera (Collingwood 1985; Collingwood and Agosti 1996; Pesenko and Pauly 2009; Sharaf and Aldawood 2019).

Our analysis of species endemism is distinctly higher than the degree of endemism of numerous animal groups which include the works of Cowie (1989) for the Arabian Isoptera (24%), Abdel-Dayem et al. (2018) for the Carabidae of Garf Raydah (southern KSA) (19.3%), Larsen (1984) for the Rhopalocera (15.5%), Collingwood (1985) for the Formicidae of the KSA (11%), Collingwood and Agosti (1996) for the Formicidae of the Arabian Peninsula (25%), Abdel-Dayem et al. (2019) for the Carabidae of Shada Al-A'Ala Nature Reserve (KSA) (5.3%), Abdel-Dayem et al. (2017) for the Carabidae of the beetle fauna of Rawdhat Khorim National Park (KSA) (6.0 %), Penati and Vienna (2006) for the Histeridae (7.5%).

The ant genus *Lepisiota* along with two other genera (*Camponotus* Mayr, 1861 and *Cataglyphis* Foerster, 1850) are the most diverse and abundant genera of the subfamily Formicine both in Oman and in the entire Arabian Peninsula (Collingwood 1985; Collingwood and Agosti 1996; Sharaf et al. 2018). They are represented in Oman by the following number of species; *Camponotus* (18), *Cataglyphis* (15) and *Lepisiota* (15). In the Arabian Peninsula the number is as follows; *Camponotus* (25), *Cataglyphis* (28) and *Lepisiota* (26). An inventory in the southwestern mountains of the KSA using several collecting techniques (Pitfall, Malaise, and light traps) revealed a similar pattern of abundance and diversity of the three genera (Sharaf et al. unpublished data).

Among this remarkable abundance and diversity of many species of *Lepisiota*, however, there are some rare species known only from a few specimens, e.g. *Lepisiota arabica* Collingwood, 1985 (5), *L. dhofara* Collingwood & Agosti (1), *L. dammama* Collingwood & Agosti (5), *L. elbazi* sp. nov. (2), and *L. omanensis* Sharaf & Monks, 2016 (5). Not only are there morphological similarities between *L. elbazi* and its congener *L. arabica* but they have similar habitat preferences with both species appearing to prefer the mountainous territories of the Dhofar Governorate for *L. elbazi* and the southwestern mountains of the KSA for *L. arabica*.

The taxonomic keys for the *Lepisiota* fauna of the KSA (Collingwood 1985) and the Arabian Peninsula (Collingwood and Agosti 1996) have some degree of apparent ambiguity in some of their parts, which results in the difficulty of species identification. Therefore, interested workers in the region must be careful when dealing with these two keys.

Acknowledgments

We thank the following colleagues: Barry Bolton for suggestions that improved the work; Brian Taylor, Xavier Espadaler, Boris Kondratieff, and Georg Fischer for valuable comments; Brian Fisher, Michele Esposito (California Academy of Sciences, San Francisco) for imaging the species; Annette Patzelt for appreciated permission to use image of Ayn Sahlanot, Saif Al-Hatmi (Oman Botanic Garden) for support during the field work in Oman, and A. Shams Al Ola for technical assistance. Mostafa Sharaf thanks the following colleagues for making material available for the study and ap-

preciated hospitality in the UK.: James Hogan (OUMC), Andrew Polaszek (BMNH), Stephen Judd, and Tony Hunter (World Museum Liverpool, Liverpool, U.K.). This work was supported by the Deanship of Scientific Research at King Saud University [RG-1438-010].

References

- Abdel-Dayem MS, Fad HH, El-Torkey AM, Elgharbawy AA, Aldryhim YN, Kondratieff BC, Al Ansi AN, Aldhafer HM (2017) The beetle fauna (Insecta, Coleoptera) of the Rawdhat Khorim National Park, Central Saudi Arabia. *ZooKeys* 653: 1–78. <https://doi.org/10.3897/zookeys.653.10252>
- Abdel-Dayem MS, Rasool I, Elgharbawy AA, Nagel P, Aldhafer HM (2018) Faunistic inventory and zoogeographical analysis of the ground beetles (Coleoptera, Carabidae) of Garf Raydah Nature Reserve, Southwestern of Saudi Arabia, and description of a new species of Paussinae. *Zootaxa* 4514(3): 341–371. <https://doi.org/10.11646/zootaxa.4514.3.3>
- Abdel-Dayem MS, Elgharbawy AA, Rasool I, Nagel P, Aldhafer HM (2019) The Carabidae (Coleoptera) of Shada Al-A'Ala Nature Reserve, Southwestern Saudi Arabia, with description of a new species of Paussinae. *ZooKeys* 812: 93–131. <https://doi.org/10.3897/zookeys.812.30937>
- Agosti D, Collingwood CA (1987) A provisional list of the Balkan ants (Hym. Formicidae) with a key to the worker caste. II. Key to the worker caste, including the European species without the Iberian. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 60: 261–293.
- André E (1882) Les fourmis [part]. In: André E (Ed.) *Species des Hyménoptères d'Europe et d'Algérie*. Tome Deuxième. Edmond André 919, Beaune, 153–232.
- Arakelian GR (1994) Fauna of the Republic of Armenia. Hymenopterous insects. Ants (Formicidae). Gitutium, Erevan, 153 pp. [In Russian.]
- Arnold G (1920a) A monograph of the Formicidae of South Africa. Part IV. Myrmicinae. *Annals of the South African Museum* 14: 403–578.
- Arnold EN (1980) The reptiles and Amphibians of Dhofar, Southern Arabia. *Journal of Oman Studies Special Report No. 2*: 273–332.
- Atanassov N, Dlussky GM (1992) Fauna of Bulgaria. Hymenoptera, Formicidae. *Fauna na Bûlgariya* 22: 1–310. [In Bulgarian.]
- Ball L, Al-Fazari W, Borrell JS (2015) Birds of Wadi Sayq, Dhofar, Oman: British Exploring Society Expeditions January-March 2012 and 2013. *Sandgrouse* 37(1): 2–12.
- Bestelmeyer BT, Schooley RL (1999) The ants of the southern Sonoran Desert: community structure and the role of trees. *Biodiversity and Conservation* 8: 643–657. <https://doi.org/10.1023/A:1008873406658>
- Bingham CT (1903) The fauna of British India, including Ceylon and Burma. Hymenoptera (Vol. II). Ants and Cuckoo-wasps. Taylor and Francis, London, 506 pp.
- Bolton B (1973) The ant genera of West Africa: a synonymic synopsis with keys (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History). Entomology* 27: 317–368.

- Bolton B (1994) Identification Guide to the Ant Genera of the World. Harvard University Press, Cambridge, 222 pp.
- Bolton B (1995) A New General Catalogue of the Ants of the World. Harvard University Press, Cambridge, 504 pp.
- Bolton B (2020) An online catalog of the ants of the world. <http://antcat.org>. [accessed 9 January 2020]
- Boulton AM, Davis KF, Ward PF (2005) Species richness, abundance, and composition of ground-dwelling ants in northern California grasslands: role of plants, soil, and grazing. *Environmental Entomology* 34: 96–104. <https://doi.org/10.1603/0046-225X-34.1.96>
- Brown Jr WL (2000) Diversity of ants. In: Agosti D, Majer JD, Alonso LE, Schultz TR (Eds) *Ants. Standard Methods for Measuring and Monitoring Biodiversity*. Biological diversity Handbook Series. Smithsonian Institution Press, Washington, 45–79.
- Collingwood CA (1985) Hymenoptera: Fam. Formicidae of Saudi Arabia. *Fauna of Saudi Arabia* 7: 230–302.
- Collingwood CA, Agosti D (1996) Formicidae (Insecta: Hymenoptera) of Saudi Arabia (part 2). *Fauna of Saudi Arabia* 15: 300–385.
- Collingwood CA, Agosti D, Sharaf MR, Van Harten A (2011) Order Hymenoptera, family Formicidae. *Arthropod Fauna of the UAE* 4: 405–474.
- Cowie RH (1989) The zoogeographical composition and distribution of the Arabian termite fauna. *Biological Journal of the Linnean Society* 36: 157–168. <https://doi.org/10.1111/j.1095-8312.1989.tb00488.x>
- Dalla Torre KW (1893) *Catalogus Hymenopterorum Hucusque Descriptorum Systematicus et Synonymicus* (Vol. 7). Formicidae (Heterogyna). W. Engelmann, Leipzig, 289 pp. <https://doi.org/10.5962/bhl.title.8794>
- Delany MJ (1989) The zoogeography of the mammal fauna of southern Arabia. *Mammal Review* 19(4): 133–152. <https://doi.org/10.1111/j.1365-2907.1989.tb00408.x>
- El-Hawagry MS, Khalil MW, Sharaf MR, Fadl HH, Aldawood AS (2013) A preliminary study on the insect fauna of Al-Baha Province, Saudi Arabia, with descriptions of two new species. *ZooKeys* 274: 1–88. <https://doi.org/10.3897/zookeys.274.4529>
- El-Hawagry MS, Al Dhafer HM (2015) Five new records of bee flies (Bombyliidae, Diptera) from Saudi Arabia with zoogeographical remarks. *ZooKeys* 489: 125–133. <https://doi.org/10.3897/zookeys.489.8794>
- El-Hawagry MS, Abdel-Dayem MS, Elgharbawy AA, Dhafer HM (2016a) A preliminary account of the fly fauna in Jabal Shada al-A'la Nature Reserve, Saudi Arabia, with new records and biogeographical remarks (Diptera, Insecta). *ZooKeys* 636: 107–139. <https://doi.org/10.3897/zookeys.636.9905>
- El-Hawagry MS, Sharaf MR, Al Dhafer HM, Fadl HH, Aldawood AS (2016b) Addenda to the insect fauna of Al-Baha Province, Kingdom of Saudi Arabia with zoogeographical notes. *Journal of Natural History* 50(19–20): 1209–1236. <https://doi.org/10.1080/00222933.2015.1103913>
- El-Hawagry MS, Abdel-Dayem MS, El-Sonbati SA, Al Dhafer HM (2017) A preliminary account of the fly fauna in Garf Raydah Nature Reserve, Kingdom of Saudi Arabia, with new

- records and biogeographical remarks (Diptera: Insecta). Journal of Natural History 51: 1499–1530. <https://doi.org/10.1080/00222933.2017.1347299>
- El-Hawagry MS, Al Dhafer HM, Abdel-Dayem MS (2019) On the fly fauna of the central region of the Kingdom of Saudi Arabia: new country records from Riyadh Region, with a list of associated fly species and zoogeographical remarks (Insecta: Diptera). Journal of Natural History 53: 17–43. <https://doi.org/10.1080/00222933.2019.1568601>
- Emery C (1892) Sopra alcune formiche raccolte dall'Ingegnere L. Bricchetti Robecchi nel paese dei Somali. Dummy reference. Annali del Museo Civico di Storia Naturale 32[=(2)12]: 110–122.
- Emery C (1897) Formiche raccolte da Don Eugenio dei Principi Ruspoli, durante l'ultimo suo viaggio nelle regioni dei Somali e dei Galla. Annali del Museo Civico di Storia Naturale 38[=(2)18]: 595–605.
- Emery C (1901) Spicilegio mirmecologico. Bullettino della Società Entomologica Italiana 33: 57–63.
- Ficetola GF, Mazel F, Thuiller W (2017) Global determinants of zoogeographical boundaries. Nature Ecology and Evolution 1: 1–7. <https://doi.org/10.1038/s41559-017-0089>
- Finzi B (1936) Risultati scientifici della spedizione di S. A. S. il Principe Alessandro della Torre e Tasso nell'Egitto e penisola del Sinai. XI. Formiche. Bulletin. Société Entomologique d'Egypte 20: 155–210.
- Forel A (1892) Notes myrmécologiques. Annales de la Société Entomologique de Belgique 36: 38–43.
- Forel A (1910) Ameisen aus der Kolonie Erythräa. Gesammelt von Prof. Dr. K. Escherich (nebst einigen in West-Abessinien von Herrn A. Ilg gesammelten Ameisen). Zoologische Jahrbücher. Abteilung für Systematik, Geographie und Biologie der Tiere 29: 243–274.
- Forel A (1911) Fourmis nouvelles ou intéressantes. Bulletin de la Société Vaudoise des Sciences Naturelles 47: 331–400.
- Forel A (1913) Formicides du Congo Belge récoltés par MM. Bequaert, Luja, etc. Revue Zoologique Africaine (Brussels) 2: 306–351.
- Guichard KM (1980) A preliminary account of the sphecid wasps of Oman (Hymenoptera, Sphecidae). The Journal of Oman Studies, Special Report 2: 223–232.
- Hájek J, Reiter A (2014) Adephagous water beetles (Coleoptera: Gyrinidae, Haliplidae, Noteridae, Dytiscidae) of Yemen and Dhofar region (Oman) with description of a new Hyphydrus from Socotra Island. Acta Entomologica Musei Nationalis Pragae 54: 63–99.
- Hausmann A (2009) New and interesting geometrid moths from Dhofar, southern Oman (Lepidoptera, Geometridae). Mitteilungen der Münchner Entomologischen Gesellschaft 99: 111–128.
- Hita Garcia F, Wiesel E, Fischer G (2013) The ants of Kenya (Hymenoptera: Formicidae) faunal overview, first species checklist, bibliography, accounts for all genera, and discussion on taxonomy and zoogeography. Journal of East African Natural History 101: 127–222. <https://doi.org/10.2982/028.101.0201>
- Karavaiev V (1912) Ameisen aus Tunesien und Algerien, nebst einigen unterwegs in Italien gesammelten Arten. Russkoe Entomologicheskoe Obozrenie 12: 1–22.
- Kuznetsov-Ugamsky NN (1929) Die Gattung *Acantholepis* in Turkestan. Zoologischer Anzeiger 82: 477–492.

- Larsen TB (1980) The butterflies of Dhofar and their zoogeographic composition. *Journal of Oman Studies Special Report* 2: 153–186.
- Larsen TB, Larsen K (1980) *The Butterflies of Oman*. Bartholomew, Edinburgh, 80 pp.
- Larsen TB (1984) The zoogeographical composition and distribution of the Arabian butterflies (Lepidoptera: Rhopalocera). *Journal of Biogeography* 11: 119–158. <https://doi.org/10.2307/2844685>
- Mayr G (1855) *Formicina austriaca*. Beschreibung der bisher im österreichischen Kaiserstaate aufgefundenen Ameisen, nebst Hinzufügung jener in Deutschland, in der Schweiz und in Italien vorkommenden Arten. *Verhandlungen der Zoologisch-Botanischen Vereins in Wien* 5: 273–478.
- Melnikov D, Pierson T (2012) A new species of *Pseudotrapelus* (Agamidae, Sauria) from Dhofar, Oman. *Current Herpetology* 12: 143–151.
- Neubert E, van Damme D (2012) Palaeogene continental molluscs of Oman. *Contributions to Natural History* 20: 1–21.
- Penati F, Vienna P (2006) An updated catalogue of the Histeridae (Insecta: Coleoptera) of the Arabian Peninsula, with biogeographical remarks. *Zootaxa* 1157: 1–74. <https://doi.org/10.11646/zootaxa.1157.1.1>
- Pesenko YA, Pauly A (2009) A contribution to the fauna of the Nomioidine bees of the Arabian Peninsula (Hymenoptera: Halictidae). *Fauna of Arabia* 24: 217–236.
- Rueda M, Rodríguez MÁ, Hawkins BA (2013) Identifying global zoogeographical regions: lessons from Wallace. *Journal of Biogeography* 40: 2215–2225. <https://doi.org/10.1111/jbi.12214>
- Schneider W, Krupp F (1993) Dragonfly Records from Saudi Arabia with an annotated checklist of the species from the Arabian Peninsula (Insecta: Odonata). *Fauna of Saudi Arabia* 13: 63–78.
- Sharaf MR, Al Dhafer HM, Aldawood AS (2014) First record of the myrmicine ant genus *Meranoplus* Smith, 1853 (Hymenoptera: Formicidae) from the Arabian Peninsula with description of a new species and notes on the zoogeography of southwestern Kingdom Saudi Arabia. *PLoS ONE* 9(11): e111298. <https://doi.org/10.1371/journal.pone.0111298>
- Sharaf MR, Aldawood AS (2011) *Monomorium dryhimi* sp. n., a new ant species (Hymenoptera, Formicidae) of the *M. monomorium* group from Saudi Arabia, with a revised key to the Arabian species of the group. *ZooKeys* 106: 47–54. <https://doi.org/10.3897/zookeys.106.1390>
- Sharaf MR, Aldawood AS (2019) Review of the ant genus *Meranoplus* Smith, 1853 (Hymenoptera: Formicidae) in the Arabian Peninsula with description of a new species *M. mosalahi* sp. n. from Oman. *PeerJ* 7:e6287. <https://doi.org/10.7717/peerj.6287>
- Sharaf MR, Aldawood AS, Taylor B (2012a) A new ant species of the genus *Tetramorium* Mayr, 1855 (Hymenoptera, Formicidae) from Saudi Arabia, including a revised key to the Arabian species. *PLoS ONE* 7(2): e30811. <https://doi.org/10.1371/journal.pone.0030811>
- Sharaf MR, Aldawood AS, El-Hawagry MS (2012b) A new ant species of the genus *Tapinoma* (Hymenoptera, Formicidae) from Saudi Arabia with a key to the Arabian species. *ZooKeys* 212: 35–43. <https://doi.org/10.3897/zookeys.212.3325>

- Sharaf MR, Aldawood AS, El-Hawagry MS (2012c) First record of the ant subfamily Aenictinae (Hymenoptera, Formicidae) from Saudi Arabia, with the description of a new species. ZooKeys 228: 39–49. <https://doi.org/10.3897/zookeys.228.3559>
- Sharaf MR, Fisher BL, Al Dhafer HM, Polaszek A, Aldawood AS (2018) Additions to the ant fauna (Hymenoptera: Formicidae) of Oman, updated list, new records and description of two new species. Asian Myrmecology 9: e010004. [1–38]
- Sharaf MR, Monks J, Polaszek A, Aldawood SA (2016) A remarkable new species of the genus *Lepisiota* Santschi (Hymenoptera: Formicidae) from Oman and the United Arab Emirates with a key to the Arabian species. Journal of Natural History 50(29–30): 1875–1887. <https://doi.org/10.1080/00222933.2016.1180722>
- Šmíd J (2010) New remarkable snake records from Oman. Herpetology Notes 3: 329–332.
- Smith F (1861) Descriptions of some new species of ants from the Holy Land, with a synonymic list of others previously described. Journal and Proceedings of the Linnean Society of London. Zoology 6: 31–35. <https://doi.org/10.1111/j.1096-3642.1861.tb00926.x>
- Taiti S, Ferrara F, Davolos D (2000) The terrestrial Isopoda (Crustacea: Oniscidea) of Oman. Fauna of Arabia 18: 145–163.
- Waterston AR, Pittaway, AR (1991) The Odonata or dragonflies of Oman and neighbouring territories. Journal of Oman Studies 10: 131–168.
- Wu J, Wang C (1995) The ants of China. China Forestry Publishing House, Beijing, 214 pp. [In Chinese]
- Zhou S (2001) Ants of Guangxi. Guangxi Normal University Press, Guilin, 255 pp. [In Chinese]